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AN ASSESSMENT OF THE FCIM DSS
FOR THE EFFECTS OF LEAD TIME
ON PROCUREMENT DECISIONS

by

Robert C. Douglass

December, 1992

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An Assessment of the FCIM DSS
for the Effects of Lead Time
on Procurement Decisions

by

Robert C. Douglass
Lieutenant, Supply Corps, United States Navy
B.S., Drexel University, 1977

Submitted in partial fulfillment
of the requirements for the degree of

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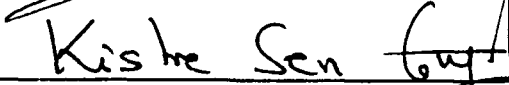
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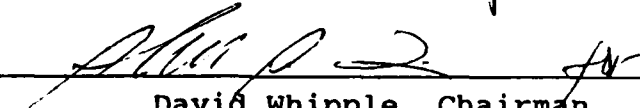
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ABSTRACT

The development of automated manufacturing technology and the creation of Department of Defense (DOD) RAMP facilities which use this technology has required the development and use of improved decision support software (DSS) products. The new technology has allowed the facilities to reduce procurement lead time in the manufacturing process which now must be factored into the procurement and inventory management of the Navy and the DOD.

This thesis examines a DSS product developed by Fleet Material Support Office for the RAMP Project Office which compares competing bids from RAMP sites and private contractors for the manufacture of repair parts. The DSS uses a modified version of the Wilson economic order quantity formula to determine optimum quantities to buy, minimizing the total relevant cost. It will be used to decide between competing bids which may vary in unit price, and delivery schedules.

The author concludes that the theory for the calculation of total relevant cost is adequate but that reports generated do not highlight the benefits of reduced lead time and have significant computational errors.

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I. INTRODUCTION

The purpose of this thesis is to assess a decision support software (DSS) being provided by the Fleet Material Support Office (FMSO) to the Rapid Acquisition of Manufactured Parts (RAMP) Project Office. The DSS is designed to indicate a choice between competing bids for parts being produced by RAMP manufacturing sites and produce written reports for documentation of procurement decisions.

The unique nature of the parts being produced, which have long lead times and limited sources of supply, has been the motivation for the development of an in-house manufacturing capability to reduce lead times. However, the current procurement decision models do not explicitly evaluate and document trade-offs between lead time and price. The DSS, which will be provided to inventory and contracting management personnel, is expected to produce the evaluation documentation in support of acquisitions where lead time and not unit price may be the deciding factor.

The remainder of the introduction provides an overview of the procurement and contracting environment, identifies the particular problems being experienced by the RAMP Project Office in achieving its strategic objectives, and reviews the literature on the economic order quantity formula being used by the DSS.

A. ENVIRONMENT

For items being inventoried, the determination of how much of a particular item to buy and store has been based on a combination of factors including: price, ordering costs, holding costs, shortage costs, and the administrative and production lead times. These factors, used in economic order quantity formulas, establish inventory decision points critical to inventory management. The decision points include the reorder point, safety level, and economic order quantity.

The potential suppliers have generally provided bids for required products that were very similar in both price and lead time. Given that the value of lead time differences were not stated in dollar terms, procurement personnel concentrated on price in the selection of the best bid (ASO Inventory Manager Interview, 1992).

One portion of the inventory items, however, has consistently required extra attention. These are characterized as low demand, long lead time, and soon to be obsolete. These items are almost exclusively replacement parts for weapon systems. The civilian contractors who originally provided these parts may no longer be in business and the weapons systems may no longer be in production (RAMP Implementation Manager Interview, 1992). If such a part is required for a weapon system, however, that system becomes either degraded or not operational which may seriously affect the readiness of

the military unit. If a conflict occurs, the degraded or non-operational system could lead to loss of life.

This situation has led to various solutions. In some cases, large quantities of parts representing the expected life cycle requirement have been purchased with the hope that no additional parts would be required to support the particular weapon system. Inventory holding costs, which include the investment and warehousing cost, and the disposal of obsolete leftover parts at the phase out of the weapon system, generally have made this method unacceptable and led to regulations limiting quantities to be purchased (OPNAV INST. 4440.23, 1976). Another method has been to wait until an inventory shortage exists and then pay a civilian contractor to produce limited quantities of the item on a rush basis. The costs per unit may increase in such situations because the contractor may seek compensation for the quick response and limited production run. In addition to the unit cost, the shortage cost may also be high because of the loss of life when the weapon system is not available because of the inventory shortage.

To address this problem and reduce the cost of weapon system support, NAVSUP investigated emerging technologies for the manufacture or procurement of these hard to support items (Gardner, 1988). In a strategic plan approved by Congress, NAVSUP established the RAMP Project Office to develop the computer integrated manufacturing (CIM) technology, field a

CIM capability, if cost justified, and eventually transfer this technology to the private sector. The strategic plan to accomplish these three steps identified the following critical factors which would need to be accomplished for successful implementation (RAMP Strategic Plan, 1989):

- Standardize Digital Technical Data Packages and Communications
- Successfully Demonstrate Manufacturing Capability
- Justify Cost/Benefits
- Integrate the Technology and Capability into the Supply System
- Optimize Supply Response Time
- Integrate into Weapon System Acquisition
- Transfer Technology to DOD Industrial Activities and the Civilian Manufacturing Sector

Project personnel have developed the technology for the technical data packages and communications and they are now fielding a manufacturing capability to produce many of the parts required. These facilities, in their initial production runs, have been able to reduce the lead time from that currently being provided by private sector contractors (RAMP Implementation Presentation, 1991). RAMP project personnel are now integrating the technology and capability into the supply system. The benefits of automated manufacturing have been successfully justified (Gardner, 1988), new accounting systems

have been suggested (Bryant, 1988; Goodwin, 1991), and performance measurement systems developed (Martin, 1989).

In order to achieve integration, item managers at the Ships Parts Control Center (SPCC) and the Aviation Support Office (ASO) must identify parts which meet the manufacturing and supply support criteria. Once identified, the technical specifications of the parts must be reduced to automated manufacturing instructions which will be re-used each time the part is required. Inventory managers and contracting personnel must coordinate their procurement requirements and procedures for the parts identified to maximize the Navy's flexibility and minimize the costs of procurement (SPCC Interview, 1992).

In recent months, more than 200 parts have been identified by ASO and SPCC. The technical data packages for these parts have been reduced to the required computer format and the required quantities of these parts for inventory and immediate needs forwarded to the RAMP sites for bids (RAMP Project Office and SPCC Interview, 1992).

Bids for individual parts received from the RAMP sites confirm the reduction in production lead time compared with the last procurement of those parts. The unit price, however, is higher than bids from the private contractors with longer lead times (RAMP Implementation Manager Presentation 1992).

Integration of RAMP sources of supply into the supply system necessitates the competition between unit price and lead time in the selection of competing bids. Buyers and

managers have, as a result of their routine experiences of the past, considered the lowest unit price the deciding factor in awarding contracts. This has lead to the selection of lower unit cost bids when higher unit cost bids with lower lead times were available (RAMP Implementation Manager Interview, 1992).

Confronted with this tendency, the RAMP Project Office has sought the Flexible Computer Integrated Manufacturing (FCIM) DSS being provided by FMSO to evaluate competing bids taking into account varying lead times. The FCIM DSS needs to produce reports detailing all of the relevant facts concerning the procurement and provide sufficient evidence to support an award where reduced lead time would override a difference in unit price. The documentation should show the best bid at the lowest total relevant cost and the benefits of reduced lead time in the calculation of the safety level, economic order quantity, and reorder point. The purpose of this thesis is to evaluate the FCIM DSS being provided by FMSO and determine if the FCIM DSS meets the goal of a fair evaluation of competing bids.

B. MODEL DEVELOPMENT

Rather than develop a totally new model, FMSO modified and existing model called Q-Star (Q*) which was developed for SPCC but never implemented (Project Q*, undated). The Q* model was developed to automate procedures for evaluating bids if price

breaks/quantity discounts and varying lead times would apply. The Q* model was to be used for a limited group of items with steady demand if there was reason to believe that item price would be affected by order quantity size. The model was not to be used for items with the characteristics shown in Table I:

Table I CHARACTERISTICS NOT INCLUDED IN Q*

Repairables

Provisioning Items

Items with Downward Tending Demand

Items for Equipments in Phase Out

Program Based Items with High Variance

Items on Indefinite Delivery Orders or Buys
using Forward Pricing Data

Sole Source Greater than \$100,000.

Competitive Source Greater than \$200,000

Source: Project Q*, undated

RAMP parts violate several of these constraints. In particular those that refer to items with a downward tending demand or for equipment in phase out. The affect of these limitations on the FCIM DSS are discussed in Chapter III.

The FCIM DSS uses the Wilson economic order quantity (EOQ) formula as the basis for its calculation of the total relevant costs of a procurement, reorder point and safety level.

The literature on the Wilson EOQ is extensive with critics as well as supporters (e.g., Woolsey, 1988; Jones, 1991). The basic model applies the formula shown below:

$$TEC = CIQ/2 + SR/Q \quad \text{Where } TEC = \text{Total Expected Cost}$$

C is the cost of the item in Dollars/Unit

I is the holding rate in percent of
price/item/unit of time

S is the set up cost or ordering cost in Dollars/Order

R is the annual requirement in Units

Q is the order quantity in Number of Items/Order

(Woolsey, 1988)

Woolsey suggests that many of the variables listed are not as certain as the definitions would imply and that because of this the EOQ model should not be used. He points out that the cost of a item may be radically affected by the current inflation rate and the cost accounting system in use. The holding rate, which is discussed later, is questioned because of its traditional assignment as the cost of money (i.e., the prime rate plus points). The argument is that the holding rate should really be the rate of return on the product being produced with the highest mark up. Using this higher rate, a small error in the estimate of an EOQ will create a greater error in the total expected cost. The set up cost and the annual requirement (i.e., demand forecast) are challenged as merely estimates which can not be determined with sufficient accuracy on which to base an inventory decision. Finally, the

static model presented above assumes that demand is constant over time (Woolsey, 1988).

Woolsey's arguments attack the static EOQ model but do not suggest any alternative. Jones (1991) however, takes the traditional EOQ model and develops an explanation for why its current use does not match the emerging just in time (JIT) inventory management recommendations. Jones argues that only short run variable costs have traditionally been considered lot size dependent. He suggests adopting a more comprehensive view of which costs are relevant which creates a more meaningful EOQ. According to Jones, costs not previously considered were excluded because (Jones, 1991, pg 57):

- The costs are not linearly variable.
- A reduction in a lot size for a particular item will have little effect on total costs.
- When established as fixed, costs stay fixed.

For instance, reducing the lot size of a single item at a supply center will have little effect on the depots operating costs and facilities. If, however, a majority of the items were managed as JIT inventory, operating costs and the facilities required would be reduced. In addition, Jones would argue that the management of the supply center would try to retain personnel and facilities keeping these costs fixed.

Continuing the comparison of JIT and EOQ recommendations, Jones adjusts the carrying costs of inventory in the EOQ model for a more complete definition of carrying costs. This

produces an EOQ which is modestly higher than JIT recommended quantity. Jones reconciles the remaining difference between the JIT and EOQ model recommendations by suggesting several non-quantitative benefits which may be attributable to the JIT environment. He concludes that the EOQ model is primarily applicable to purchase orders and not production and that the EOQ model is reliable if employed correctly.

The principle criticisms made by Woolsey (1988) of the EOQ model involve the establishment of fixed estimates of certain costs and the variation that occurs in demand and lead time. In order for the FCIM DSS to accommodate these criticisms, the use of probability distributions for the calculation of the EOQ, safety level and reorder point were incorporated by the designers at FMSO. The original inventory control model, Q^* , used a normal distribution for demand to calculate the inventory decision points. To accommodate low demand items which were originally excluded, the Q^* model was modified to include a Poisson distribution where appropriate. Inputs by the user in the new FCIM DSS are for the variation in lead time demand and would not include a previously available opportunity in the Q^* model to input a separate factor for the variance in lead time (Project Q^* , undated). This input parameter is discussed more in Chapter II. The variance in lead time has been shown to have a significant effect on stock out costs and, as is shown later, is an important factor in the evaluation of RAMP type items (Mayer, 1984).

Both Woolsey (1988) and Jones (1991) express concern over the establishment of the holding cost rate. The FCIM DSS provides for the entry of a holding cost rate which is discussed in the presentation of the input parameters in Chapter II.

C. THESIS ORGANIZATION

The FCIM DSS model is presented in the next chapter where all of the inputs and outputs used are discussed. The model is then tested for computational accuracy in programming and usability by the RAMP Project Office and inventory managers and the results presented in Chapter III. The model is then used to make an assessment of the value of lead time. In Chapter IV, the results are summarized. Also, conclusions and recommendations are provided to both the RAMP Project Office and FMSO.

II. PRESENTATION OF THE MODEL

A. INTRODUCTION

The FCIM DSS receives input from the user, evaluates this input, and produces documentation to support a procurement choice. The system is designed to be used by a procurement official responsible for the award of a contract to a prospective contractor. Currently, prospective contractors are DOD industrial activities that have the RAMP automated manufacturing technology. The assessment of the FCIM DSS was conducted in two stages. The first stage was to determine if the system was operating as specified. The second stage was to determine if its outputs met the goals of the RAMP project office. Sample data were provided by SPCC, ASO and the RAMP Project Office. The data included bids for required quantities of RAMP type items and inventory manager data on the historical demand and current inventory decision points for the items.

The FCIM DSS requires the entry of item data, current material requirements, vendor data, and parameter data for an evaluation of bids for the procurement of a particular part. In this chapter, each of these data groups is discussed separately. Output reports present the results of the

evaluation and are designed to be used to document the decision to award to a particular vendor.

In Chapter III, the sample data provided by the RAMP Project Office, SPCC and ASO is introduced and the results tested.

B. ITEM DATA

Item data entered in the FCIM DSS is generated from the existing item manager files or must be estimated by procurement personnel. The item data represents the latest available historical information on the part being considered for procurement. For this analysis, some of the data elements were readily available for input (see Table II) while others required estimation or approximation. Assumptions used to generate the approximations for the analysis are provided below and a detailed description of all of the elements is included in Appendix A.

1. Estimated Data Elements

Elements for which the input data were estimated are listed below with an explanation of the assumptions made for this analysis.

Mean Absolute Deviation (MAD)

The mean absolute deviation (MAD), a measure of the variation in quarterly demand and lead time, could be

Table II AVAILABLE DATA ELEMENTS

Quarterly Demand
Production Lead Time
Reorder Point
Economic Order Quantity
Unit Price
Catalog Code
Item Name
Shelf Life

calculated more precisely by a specific user if the item manager transactions files were reviewed in detail for the item being ordered. However, a previous study completed at FMSO provided an estimating formula which can be used instead of the calculation of the specific data element for a particular item. The estimating formula was used for this analysis and may be used with the FCIM DSS. The formula was developed from a much larger population which included all of the different categories of material handled by SPCC (FMSO Interview, 1992). As will be shown later, this formula probably under estimates the variation in demand for the RAMP eligible items.

$$MAD = 1.37 D^{0.72}$$

Where MAD = Mean Absolute Deviation of Lead Time Demand

and $D = \text{Quarterly Demand}$

Quarterly Requirements

Quarterly requirements reflects the number of times during the quarter an item is requested. For this analysis, the element was estimated based on the unit of issue of the item and quantity expected to be requested on each requisition. If items had a quarterly demand of less than 20 or it was an item that had characteristics similar to those low demand items, then the quarterly requirement was set equal to the quarterly demand. If quarterly demand was greater than 20, then the quarterly requirement was set equal to one tenth the quarterly demand. For example, if quarterly demand were 12, then the quarterly requirement was set equal to 12; if the quarterly demand was 150, then the quarterly requirement was set equal to 15.

This element, used in conjunction with the MAD, affects the computation of the inventory decision points of the item and the total relevant cost of a bid being evaluated.

Procurement Lead Time

Item manager data included the previously experienced production lead times. For this analysis, an estimate of the procurement administrative lead time of 150 days was added to create the procurement lead time data element (RAMP

Implementation Presentation, 1991). This estimate reflects the status of procurement prior to the implementation of RAMP and does not reflect the possible savings in lead time that RAMP automated administrative bid procedures may provide in the future. The RAMP Project Office has established a goal of reducing the administrative portion of the procurement lead time to three days (RAMP Implementation Presentation 1991).

C. CURRENT MATERIAL REQUIREMENTS

The current material requirement (CMR) is the next element to be entered in the FCIM DSS for the evaluation of a proposed procurement. CMR's are entered as individual purchase requests and are then consolidated by the system to a total requirement. The original Q* model was developed for use by SPCC. The SPCC inventory control system generated buy recommendations on a periodic basis. These buys were in conjunction with requirements for inventory, not immediate needs. As a result, a separate set of equations was introduced in Q* and continued in the FCIM DSS to establish a modified CMR as shown below.

If Sum of "Buys" < EOQ

Then set CMR = Sum of "Buys"

If Sum of "Buys" > EOQ

Then set CMR = Sum of "Buys" - EOQ

This procedure was established because of long lead times in procurement which lead to multiple buy requirements being generated in the SPCC inventory control system. Duplication in procurement for inventory was caused by the inventory control system in place and the equations above served to reduce the procurement requirement (FMSO Interview, 1992).

D. VENDOR DATA

In the vendor data section of the FCIM DSS, the bids vendors have provided for the required item are entered for the evaluation. The input provides for the minimum lot size (MLS), for a given price, and a schedule of incremental deliveries. An option in the bidding process which is currently being explored by contracting personnel, is the removal of restrictions on the vendor on the exact quantity to be provided and the date and quantity of deliveries to be made (Project Q*, undated). This option, found in the Q* model, has been included in the FCIM DSS. The Government can solicit for its minimum requirements and at the same time open up the request for bid to allow the vendor to suggest alternative quantities and delivery schedules to maximize production efficiency.

E. PARAMETER DATA

Parameter data are the fixed estimates of various constants in the FCIM DSS that are used to compute the output

elements which are discussed later. The parameter data are shown in Table III with the initial settings provided by FMSO. Following is a discussion of changes made for this analysis and changes that could be made in the future if conditions or further study warrant. Also discussed in Chapter III is the sensitivity of the total relevant cost and evaluation of bids to changes of these parameters.

Table III PARAMETER DATA

Procurement Order Cost	\$650.00
Shortage Cost	\$750.00
Minimum Acceptable Risk (Rate)	0.10
Maximum Acceptable Risk (Rate)	0.50
Holding Cost Rate	0.23
Optimal Lot Size Investment Rate	0.10
Lead Time Demand Investment Rate	0.10
Lower Bid Range Factor	1
Upper Bid Range Factor	8

1. Procurement Order and Shortage Cost

The dollar value of procurement order and shortage costs was established by studies conducted by SPCC before the development of the FCIM DSS and are still considered by FMSO personnel to be the best estimate of these costs (FMSO Interview, 1992). The dollar values are used in conjunction with the calculation of the expected shortage and the number

of procurements per year to determine the annual variable procurement and shortage costs. It is not clear that the current value for the procurement order cost captures the impact of developing automated contracting procedures which may reduce procurement costs. Also, the shortage cost may not capture the impact of reductions in military spending which may make shortages in repair parts and subsequent reductions in readiness more costly.

2. Minimum and Maximum Risk Rates

The minimum and maximum risk rates are factors in the calculation of EOQ, reorder point, safety level and expected units short. The initial value to be used in the FCIM DSS provided by FMSO for the maximum risk rate of 50 percent was reduced by the author for this analysis to 10 percent after consulting with ASO inventory managers. The ASO inventory managers are required to maintain at least 90 percent availability for all items they stock (ASO Interview, 1992).

The risk rates are used in conjunction with the estimated MAD and represent the inventory managers acceptable range of risk of not having inventory available for issue when required.

3. Holding Cost Rate

The holding cost rate to be used in the FCIM DSS was established by DOD instructions (e.g., OPNAV INST. 4440.23, 1976). The rate is a composite of the investment cost, storage

cost, and obsolescence and other losses cost. Each of the components of the holding cost rate are reviewed below.

a. Investment Cost

The investment cost portion of the holding cost rate used in the FCIM DSS was established as ten percent by DOD instruction (OPNAV INST. 4440.23, 1976). The investment in inventory by the government has been viewed as an investment foregone by the private sector (OPNAV INST. 4440.23, 1976). This rate has not been changed in recent years. Future studies of the appropriate value may be warranted given the changes in interest rates. If the long term 30 year treasury bond rate plus some risk factor were used, this investment cost might have varied between 7.5 percent and 12 percent during the last ten years and has averaged about ten percent. For the purpose of this analysis, the rate of ten percent has been accepted with the understanding that a different rate could be important in the short run will not be significant by itself in the long run.

b. Storage Cost

The storage cost portion of the holding cost rate used in the FCIM DSS was set at one percent as a result of studies conducted by various military departments and the Defense Supply Agency (OPNAV INST. 4440.23, 1976). The rate was developed by dividing the out-of-pocket costs of storage, warehousing, physical inventory operations and others,

together with the amortized cost of storage facilities into the total average inventory held. This rate has not been re-evaluated by DOD personnel who concluded that the rate represented only one percent of the total holding cost of 23 percent (OPNAV INST. 4440.23, 1976).

With the advent of automated manufacturing, however, many costs not previously included and costs normally incurred by the civilian sector may not have been included in the previous studies. Insurance, property taxes, and interest in particular, are noted as costs which the private sector is now beginning to consider in the cost of inventory (Jones, 1991). The storage cost, although previously considered small, now may deserve to be restudied in the context of the emerging JIT manufacturing environment.

c. Obsolescence Cost and Other Losses

The obsolescence cost and other losses rate, which makes up the largest portion of the holding cost rate used in the FCIM DSS, has been set at 12 percent (OPNAV INST. 4440.23). This rate was developed by dividing the average of the obsolescence costs and other losses over groups of material against the total value of the material being controlled. Given the parts currently considered for RAMP manufacture, it is likely they will experience obsolescence at a rate higher than the average. If so, they will represent a greater than average portion of the total loss experience. This suggests

that a separate grouping of those parts which are for weapon systems no longer in production and which are no longer being supported by the contractor should be re-studied for the establishment of this rate. A higher obsolescence cost rate for these items would reduce the amount of inventory at termination preventing obsolescence costs and reducing holding costs in the interim.

d. Summary for Holding Costs

The current holding cost rate used in the FCIM DSS is open to question due primarily to the lack of recent studies to affirm or correct the current rate. The investment rate portion, while the average appears appropriate, does not vary with the changing economic conditions. The storage cost and obsolescence cost portions may be understated. If so, increasing the rates would encourage tighter inventory control and help validate a higher value for the reductions in lead time which RAMP technology has made possible.

4. Optimal Lot Size and Lead Time Demand Investment Rates

The optimal lot size and lead time demand investment rates establish the value of reduced lead time and lot size when comparing alternate bids in the FCIM DSS. The rate is the same as the investment portion of the holding cost rate of ten percent. The same arguments presented for varying the investment portion of the holding cost rate apply here.

5. Upper and Lower Bid Range Factors

The upper and lower bid range factors used in the FCIM DSS represent the smallest and the largest number of calendar quarters of demand for an item for which a contract for procurement can be awarded. The upper bid range factor is limited by regulation to eight quarters of demand which has been further restricted by the Navy to six quarters of demand (FMSO Interview, 1992).

F. SUMMARY OF INPUTS

Using the item data, parameter data and vendor data, the FCIM DSS evaluates the bids and selects a bid. The bid is selected on the basis of the least total relevant cost. Several of the input parameters in use have been brought into question and warrant further study.

G. OUTPUTS

Outputs from the FCIM DSS are broken down into two sections: 1) Written reports are created in the evaluation section. 2) On screen information is provided in the sensitivity section. Both sections are described in detail and in Chapter III, these outputs are reviewed for accuracy and format to meet the requirements of the RAMP Project Office. A sample set of reports is provided in Appendix B.

H. EVALUATION SYSTEM OUTPUTS

The evaluation system produces four reports.

1. Item / Parameter / Bid Range Data Report

The FCIM DSS Item, Parameter, Bid Range Data Report lists the input for the item and parameter data selected for an evaluation. The bid range data section displays the total purchase request quantity, current material requirement, and upper and lower bid range limits. The bid range limits are calculated using the bid range factors from the parameter data, the quarterly demand item data and current material requirement.

2. Vendor Data

The FCIM DSS Vendor Data Report displays the input data for a specific vendor bid for a particular item. The heading provides the solicitation number, national stock number of the item, and the buyer's initials. The bid data includes the minimum lot size, price, and lead time for each price break and the quantity and lead time for each incremental delivery.

3. Evaluation Summary Data Report

The FCIM DSS Evaluation Summary Data Report is broken into four sections: the solicitation, quantity and price, annual variable costs, and total acquisition costs. The report brings together the inputs and evaluation by displaying the winning bid against the historical data. The calculated annual

variable costs for both the winning bid and the historical data, which have been competed against all of the bids evaluated, are displayed for comparison. The report contains all of the documentation on the evaluation of the winning bid that should be retained by the buyer to support a contract award. The formulas used to compute the costs displayed are provided in Appendix C. Each section of the report is reviewed in detail below.

a. The Solicitation

The solicitation section repeats general information from the item data, vendor data, and parameter data files. Information includes the name of the item, the item manager, buyer, method of evaluation, bid range, a list of the vendors responding, and the name of the vendor with the least total relevant cost.

Two methods are available in the FCIM DSS for evaluation of the bids: the optimal quantity method or minimum lot size method. For this analysis, the optimal quantity method was used because it does not put restrictions on the economic lot size. The minimum lot size method forces the economic order quantity to equal the minimum lot size (FMSO Interview, 1992).

b. Quantity and Price

The quantity and price section compares the price and quantity of the recommended economic lot size (ELS), the

optimal lot size (OLS) or EOQ, and the current material requirement (CMR) of the selected vendor against the historical item data referred to as the "current levels". In addition, the calculated reorder point and production lead time are displayed for information. The ELS and OLS are discussed in more detail in Chapter III.

c. Annual Variable Costs

The annual variable cost section provides the breakdown of annual variable costs, the CMR, and investment opportunity cost summing to the annual total relevant cost (TRC) for the selected vendor and the historical data.

d. Total Acquisition Costs

The total acquisition cost section displays procurement data on the total dollar value of the recommended acquisition for the selected vendor against the historical data. The recommended quantities which are used to calculate the acquisition cost are based on the FCIM DSS's choice between the EOQ, OLS and ELS. The benefit of any discount offered is shown here.

4. Detailed Vendor Evaluation Report

The FCIM DSS Detailed Vendor Evaluation Report is prepared for each vendor bid and provides the detailed results of the evaluation. The top of the report lists the solicitation number, vendor name, setup cost, first article cost, and prompt discount rate. The report is broken down into

five sections as follows: input data, computed levels data, procurement data, TRC summary data, and TRC detailed data. The formulas used to compute the costs shown on the report are provided in Appendix C. Each section of the report is detailed below.

a. Input Data Section

The input data section reports the price break and delivery schedule information entered for the identified vendor.

b. Computed Levels Data Section

The computed levels data section lists the economic lot size (ELS), optimal lot size (OLS), economic order quantity (EOQ), reorder point (RP), safety level (SL), and expected units short (EUS) computed by the FCIM DSS.

The computed EOQ is the starting point for determining the OLS and ELS and is constrained in some cases by the minimum lot size (MLS). The series of equations below show the relationship between the three computed levels as they are in the FCIM DSS.

- (1) If $EOQ \geq MLS$
- (2) Then $OLS = EOQ$
- (3) And $ELS = OLS + CMR$
- (4) If $EOQ < MLS$
- (5) Then $OLS = MLS$
- (6) AND $ELS = OLS + CMR$

c. Procurement Data Section

The procurement data section shows the recommended procurement dollar value calculated using the ELS and displays any discount offered by the vendor. Where the dollar value of the procurement is greater than the recommended procurement using the historical data, the additional outlay cost to select this vendor is displayed.

d. Total Relevant Cost Summary Data Section

The total relevant cost (TRC) summary data section displays the TRC broken down into three primary subtotal's: the annual variable cost, investment cost, and current material requirement.

e. Total Relevant Cost Detailed Data Section

The total relevant cost detailed data section breaks down the TRC summary data into its individual elements. Variable costs are broken down into the purchase cost, ordering cost, holding cost, and shortage cost. Investment costs are broken down into the optimal lot size and lead time demand investment costs. The current material requirement is repeated from the TRC summary data section.

I. SENSITIVITY ANALYSIS OUTPUTS

The sensitivity analysis provided by the FCIM DSS does not produce hard copy output reports. This portion of the model is separate from the analysis program described above and does not compare alternative bids. The inputs are the historical

item data and either a new unit price or a new lead time. Depending on the input, the sensitivity output provides either a projected lead time or unit price which is calculated from the results of an evaluation of the historical item data.

Using a step by step approach the sensitivity analysis program first calculates the expected TRC for the historical item data. Then, using either a new unit price or lead time, calculates the projected lead time or unit price holding the TRC constant. A print screen example of the entry and output report is provided in Appendix B.

III. ANALYSIS

A. INTRODUCTION

The objectives of the analysis are to validate the operation of the FCIM DSS, provide an understanding of the sensitivity of the output to changes in the input parameters, and make an overall assessment of the value of lead time in procurement decisions. To complete the analysis, several steps were required. First, item and vendor data for selected items were entered and the output reviewed for errors. Second, the item and vendor data for all of the available sample were evaluated and the results aggregated for summary analysis. The first two steps provided an understanding of the FCIM DSS system. The analysis then centered on the dollar impact of variations in lead time. Of specific interest was how a reduction in lead time might justify an increased unit price for a particular item.

B. ANALYSIS OF INPUTS AND OUTPUTS

The first tests of the FCIM DSS were to determine if the software was operating as specified and would be understandable to the anticipated operators. Deficiencies were uncovered and are detailed below.

1. Current Material Requirements

The first deficiency concerns the current material requirement (CMR) and the assumptions implicit in the model. As previously indicated, the "buys" entered into the Q* model for inventory were to be generated from the SPCC system. In the RAMP environment, where a CMR is defined as a immediate requirement in addition to any requirements for inventory, entry of CMR's leads to unexpected results. When total "buys" are less than the item data EOQ, the "buys" are set equal to the CMR and no confusion occurs. When "buys" are greater than the item data EOQ, the CMR is reduced by the EOQ and the total procurement required is misstated by an amount equal to the calculated EOQ. This procedure leads to a misstatement of the total relevant cost and acquisition cost.

2. Upper Bid Range Factor

The deficiency relating to the upper bid range factor involves a comparison of the anticipated quantity to be purchased against current regulations which prevent the acquisition for inventory of more than eight quarters of expected demand. The upper bid range factor prevents the evaluation of bids when the total purchase request is greater than the calculated upper bid range limit. This comparison of the upper bid range limit and total purchase request does not differentiate between material being procured for inventory and CMR's. Where the recommended EOQ for inventory plus the

CMR is greater than the eight quarter limitation, the FCIM DSS will recommend a quantity less than the amount needed to replenish the inventory and meet CMR's. To correct the deficiency, the upper bid range factor should calculate an upper bid range limit which will check only the anticipated procurement for inventory against the eight quarter demand limitation.

3. Vendor Data Report

The FCIM DSS Vendor Data Report, which is produced for each vendor, does not display the vendor name. This requires the user to refer back to the evaluation summary report or the detailed vendor evaluation report to determine which vendor's data is being reviewed.

4. Evaluation Summary Report

The first deficiency in the FCIM DSS Evaluation Summary Report involves the format of the report which is based on the Q* model. In the old model, the previously calculated inventory decision points generated from the historical item data represented recent information. A comparison of a current bid against these decision points would be valuable to procurement personnel. RAMP eligible parts, however, are not procured frequently making a comparison of a current bid against decision points created from historical data, in some cases three or more years old, questionable. The report would be far more useful for making

and documenting decisions if the two most competitive bids were displayed against each other with the historical decision points provided as space permits.

The historical inventory decision points also affect the calculation of the investment opportunity costs. These costs are calculated based on the differences between the bids and the historical inventory decision points. Investment cost differences, however, are only relevant when comparing between current bids and not the historical data for RAMP items, which may be out of date. If the differences between two bids is the goal, one way to obtain the investment opportunity of one bid over another without correcting this deficiency is to net the investment opportunity costs of two bids being calculated against the historical data. For example, if the investment opportunity cost of a winning bid were \$350.00 and for another bid was \$500.00, the actual investment opportunity cost of the winning bid would be only \$150.00.

The FCIM DSS does not perform one calculation which leads to a misstatement of the annual total relevant costs. The existence of a CMR suggests that a immediate requirement exists and that a shortage cost is being incurred. A computation of a shortage cost associated with the CMR is not performed. This results in an understatement of the total relevant costs. Consequently, when differences in both price and lead time exist between two bids, the model will choose the low priced bidder even though the higher priced bidder may

have a shorter lead time. The shortage costs are necessary if the model is to compute a valid comparison.

5. Detailed Vendor Evaluation Report

The FCIM DSS Detailed Vendor Evaluation Report provides the computed levels of the economic lot size (ELS), optimal lot size (OLS), economic order quantity (EOQ), reorder point (RP), safety level (SL), and expected units short (EUS). The OLS is established using the minimum lot size (MLS) determined by the buyer. This MLS equals the historical EOQ plus the CMR. The ELS, computed using the formulas presented in Chapter II, can then exceed the total of the EOQ and CMR as shown below. Assuming that the historical EOQ is the same as the computed EOQ for the selected vendor, restatement of the formulas from Chapter II results in the following:

- (1) If $EOQ < MLS$
- (2) Where $MLS = EOQ + CMR$
- (3) And $ELS = OLS + CMR$
- (4) Then $OLS = EOQ + CMR$
and substituting (4) into (3)
- (5) $ELS = EOQ + CMR + CMR$

This deficiency creates a duplication of the CMR in the computation of the ELS which leads to the incorrect calculation of procurement and comparative buy data among

vendors. One way to correct the deficiency is to add the CMR to the EOQ for the initial comparison with the MLS. The equations from Chapter II would then read as follows:

- (1) If $EOQ + CMR \geq MLS$
- (2) Then $OLS = EOQ$
- (3) If $EOQ + CMR < MLS$
- (4) Then $OLS = MLS$

C. SENSITIVITY ANALYSIS

The analysis of the sensitivity outputs was accomplished by using alternate combinations of lead time and unit price created by the analysis in the bid evaluation portion of the model as new bids. The total relevant cost (TRC) calculated in the bid evaluation portion of the model, however, did not remain constant. The expectation was that the TRC would remain constant because the combinations of lead time and price were generated in the sensitivity analysis by holding the TRC constant. The variance from the original TRC increased as the unit price and lead time moved away from the original data points. No definitive explanation was provided by FMSO for this result. A difference in rounding methods was noted, however, by programmers between the evaluation section and sensitivity analysis (FMSO Interview, 1992). For choices of lead time and unit price within ten percent of the original

values, the difference in total relevant cost was less than \$200.00.

D. SENSITIVITY AND LEAD TIME

To evaluate the sensitivity of the FCIM DSS constants and make an assessment of the value of lead time, several modifications to the available data had to be made in order to minimize the affects of the deficiencies previously discussed. Bids in response to both an inventory requirement and a CMR were assumed to be valid for just the inventory requirement quantity. This modification eliminated the affect of the CMR, the lack of a computation for a shortage cost of the CMR, and the duplication of the CMR in the ELS.

Adjusting the bids for this analysis reduced the impact of lead time on the evaluation where a shortage exists. Using the adjusted data, each constant was increased by 50 percent. The TRC was then evaluated for changes which were observed in the annual variable and investment costs. Changes in EOQ, RP, and SL were also noted. The data was then aggregated for evaluation.

1. Constants Evaluation

Each of the constants were increased by 50 percent and the increase in the TRC and annual variable cost components observed. In all cases, the TRC increased proportionally to the variable cost component being affected. For example, the procurement order cost constant was increased from \$650.00 to

\$975.00. For a bid being evaluated, this change by 50 percent increased the ordering cost from \$287.00 to \$431.00 or 50 percent. The TRC increased 6.4 percent from \$2,241.00 to \$2,395.00. The 6.4 percent increase was predicted because the original ordering costs represented 12.8 percent of the original TRC. To be able to predict how changes in constants would affect the TRC the average percentage of the TRC represented by each of the variable costs was generated. Table IV presents the breakdown of the variable costs for the 27 bids evaluated.

Table IV VARIABLE COST BREAKDOWN

<u>Variable Costs</u>	<u>Average %</u>	<u>Range</u>
Purchase	54.6	77.7 - 11.6
Ordering	20.8	72.2 - 1.8
Holding	21.3	36.8 - 13.0
Shortage	3.3	11.0 - 0.0

As expected, with an increase of 50 percent in each of the constants, the variable cost being affected would either increase by the same 50 percent or the dollar value of the increase would be spread between the other variable costs as a result of a re-computation of the EOQ, RP and SL. Table V

lists the constants and the variable costs that were affected by changes to those constants.

Table V VARIABLE OR INVESTMENT COST AFFECTED BY CONSTANT

<u>Constant</u>	<u>Variable or Investment Cost</u>
Procurement Order Cost	Ordering, Holding or Optimal Lot Size Costs
Shortage Cost	Shortage Cost
Holding Rate Cost	Ordering, Holding or Optimal Lot Size Costs
Risk Parameters	All Variable Except Purchase and Optimal Lot Size Costs
Optimal Lot Size Investment Rate	Optimal Lot Size Investment Cost
Lead Time Demand Investment Rate	Lead Time Demand Cost

Since a change in the TRC would be dependent upon the relative weight of the cost component to the TRC, an average percentage was calculated and relationships observed.

a. Observations

The ordering cost as a percentage of the total variable cost (TVC) varied inversely with the dollar size of the procurement and the quarterly demand for the item being procured. If demand or the dollar value were high, ordering costs were low as a percent of the TVC.

Shortage costs were less than three percent of the TVC throughout the analysis due to the low maximum risk rate which minimized the expected units short calculated. Consequently, changes in the shortage cost of 50 percent could only change the TVC by 1.5 percent.

Holding costs varied less than the other costs and consistently represented close to 23 percent of the TVC. Holding costs are driven by the unit price of the item being procured. If price is adjusted, the holding cost maintains the predetermined relationship of 23 percent of the price. The holding cost rate has been brought into question and, if increased, would increase holding costs proportionally.

2. Lead Time Sensitivity Analysis

The analysis of lead time was accomplished by using the sensitivity analysis section of the FCIM DSS to answer the questions: Could a ten percent increase in the unit price of an item be offset by a reduction in lead time? How much of a lead time change would be required to effect the offset?

The unit price of a winning bid for each of the items was increased and decreased by ten percent. In all cases, a ten percent increase in price reduced the average lead time to zero and would not offset the increase in unit price. The average lead time of the items checked was 150 days. A decrease in price of ten percent was offset by an increase in the acceptable lead time by at least a factor of two with an

average of four times the original lead time or 600 days. For example, the price of an item with an original unit price of \$202.53 and a production lead time of 240 days was increased by ten percent to \$222.78. This increase in price required lead time to be reduced to less than one day. A decrease of ten percent in the unit price to \$182.28 created a lead time of 575 days.

This data suggests that differences in unit price of ten percent or more, given the existing constants, will not be able to be offset by any normal variation in lead time between competing bids as observed.

E. LEAD TIME VARIANCE

The variance of lead time and its importance in the calculation of the EOQ, RP, SL and EUS have been discussed in the literature (Magson, 1979; Mayer, 1984). In the original Q* model, variance in lead time was a separate input to the relevant calculations. In the new FCIM DSS, these calculations have been consolidated using one input parameter for both the variance in lead time and demand, the MAD, which was discussed in Chapter II. The bids provided by ASO from the RAMP sites and the original lead times of those items previously produced in the private sector were reviewed with the results shown on Table VI.

The data in Table VI indicate that the RAMP manufacturing technology has improved lead time in the procurement of these

Table VI VARIANCE AND STANDARD DEVIATION

	<u>Variance</u>	<u>Std Dev.</u>	<u>AVE. LT</u>	<u># of Bids</u>
Total	2391	49	124	52
Individual RAMP Sites				
CNSY	1920	44	117	12
NAC	980	31	120	16
CP	3058	55	101	13
NOSL	2107	46	162	11
Items w/3 or more Bids				
	2401	49	128	12
Historical Item Data before RAMP				
	4794	69	364	25
CNSY Charleston Naval Shipyard				
NAC Naval Avionics Center				
CP Cherry Point				
NOSL Naval Ordinance Station Louisville				

items. Lead time decreased from 364 days to 124 days. The

standard deviation, however, although lower in absolute days, has increased from 19 percent to 38 percent of the average lead time. This suggests that either an additional input parameter for the variance in lead time be re-established or that the estimating formula for the MAD be adjusted for RAMP items. If no adjustment is made, the current estimating formula will underestimate shortage costs as a result of

unanticipated stock outs when suppliers are unable to provide the required parts within estimated variance. It is likely that as bid procedures and familiarity with the products being requested improves, the disparity in prices should become less noticeable and variance in lead times less significant. With a more accurate estimate of the MAD, the FCIM DSS will be able to properly calculate the inventory decision points and determine the expected total relevant cost for the bids being evaluated.

IV. SUMMARY, CONCLUSIONS, RECOMMENDATIONS

The FCIM DSS was evaluated for applicability of the underlying theoretical model, computational accuracy, and utility in meeting the goals of the RAMP Project Office. Also, an assessment of the value of lead time was completed to establish the limits for which lead time could be the deciding factor in a competitive bidding environment.

A. THE FCIM DSS SYSTEM

The FCIM DSS adequately applies the Wilson EOQ model. The addition of the Poisson distribution addresses the variance of lead time demand for low demand items. The FCIM DSS, however, takes a step backward from the Q^* model in the elimination of a separate parameter for the variance of lead time in the calculation of the economic order quantity, reorder point and safety level. This missing parameter may lead to more frequent stock outs and higher than anticipated shortage costs. The current estimate of the mean absolute deviation (MAD) was based on studies of items with more ready sources of supply than RAMP items. The missing parameter can be addressed by developing a different estimate for the MAD. If the variance in lead time as a percent of the average lead time for RAMP items decreases to historical levels, the missing parameter will have less affect on the management of these items.

The FCIM DSS contains computational errors and does not calculate a value for lead time if a current material requirement (CRM) exists. The use of the CMR in the FCIM DSS, as originally developed for the Q* model and the SPCC inventory control system, does not appear to be useful in the context of a RAMP procurement where various inventory control systems with differing assumptions will be in use. A more general definition of a CMR where the requirement is not for inventory is recommended.

All of the input parameter values, which were established prior to the development of the FCIM DSS, should be re-studied. The holding cost rate, which is a composite of the investment, storage and obsolescence costs, affects the value of lead time. This rate, if increased and allowed to vary with the economic conditions, could lead to changes in inventory carried. The investment portion of this rate also affects the optimal lot size and lead time demand investment costs.

Procurement order and shortage cost parameters have also been brought into question because of changes in the technology for processing orders and the importance of maintaining ready forces. Changes in all of the input parameters will affect the calculation of the inventory decision points and the total relevant cost of a procurement.

B. RECOMMENDATIONS

The following is a list of the recommendations:

- Develop a new release to correct the computation of CMR's and the establishment of the economic lot size and optimal lot size described in Chapter III, Section (B) 1 and 5.
- Reformat the evaluation summary report for comparison of current bids against each other as described in Chapter III, Section (B) 4.
- Compare investment cost differences against the winning bid and not the current levels data as discussed in Chapter III, Section (B) 4.
- Create an input parameter for the variance of lead time or generate a new estimating formula for the mean absolute deviation as described in Chapter III, Section (E).
- Re-study the parameters of the FCIM DSS including the procurement order cost, shortage cost, holding cost rate and both optimal lot size and lead time demand investment rates as discussed above and in Chapter II, Section (E) 3.

C. THE VALUE OF LEAD TIME

Lead time is an important element in the establishment of the economic order quantity, safety level, and reorder point. These inventory decision points, when evaluated with the item and parameter data, produce the total relevant cost for a procurement. No single inventory decision point or parameter defines in dollars and cents the value of a particular lead time. However, the dollar value of a reduced lead time and its benefits are seen in the changes that occur to the computed inventory decision points and the total relevant cost.

Given the current values of the parameters, reductions in lead time, though important in the financial management of the DOD's inventory, do not have as significant an affect on total relevant costs of a particular procurement as does the unit price. Unless the parameter values are changed in the FCIM DSS, unit price will continue to be the primary focus of cost containment efforts as long as the competing bids are not within ten percent of each other. If unit costs on competing bids are within ten percent of one another, lead time may then be the deciding factor.

In establishing the value of lead time and its effects on the total relevant cost, the holding cost and investment rate parameters play a major role. The currently established rates have been brought into question for further study to determine if revisions are warranted. Upward adjustments to these rates will have an affect on the computed cost of inventory and make the attainment of lower lead times a higher priority in the DOD supply system.

In conclusion, the FCIM DSS has computational errors which can be corrected. When corrected, the system will compute the total relevant cost of a proposed procurement and make a decision between competing bids. Even if these errors are corrected, however, the value of lead time may be understated because of the currently established values for the holding cost and investment rates. These rates should be reviewed. Until increases in these rates are justified by further study,

price will continue to drive the competition between bids in the FCIM DSS. Using the current holding cost and investment rates, a difference in lead time has the potential to be the deciding factor only in those cases where the difference in price between competing bids is less than ten percent.

APPENDIX A DEFINITIONS

Item Data

1. MAD Mean Absolute Deviation
A calculated value indicating variation in recurring demand observations, or recurring demand rate per program element, from the computed arithmetic mean. (Can be estimated if not available using the formula $MAD = 1.37 D^{0.72}$ (D = quarterly demand))
2. Quarterly DMD System Recurring Demand Average
The computed quantity expected to be demanded on a recurring basis from the supply system during the current quarter.
3. Quarterly REQN System Requisition Average
The computed number of requisitions expected to be received in the system during the current quarter. (Must be equal to or less than Quarterly DMD)
4. Production LT Contract Production Lead Time Average
The computed expected value (in days) of the time interval between the placement of a new contract and the receipt of the material. (Manufacture's production time only, excludes administrative lead time)
5. Procurement LT Contract Procurement Lead Time
Forecast
The computed expected value of the current period of the time interval (in days) between the initiation of the replenishment quantity and the first receipt of the material at the stocking point activities. (Must be greater than the Production LT)
6. Reorder Point System Reorder Level
Sum of stock to satisfy demand over lead time plus safety level stock over lead time.
7. EOQ System Order Quantity
The average quantity of material procured upon computation of requirements when an item reaches the reorder point.
8. Unit Price Unit Price, Item Replacement

The current price of the item that has been adjusted to the latest procurement as opposed to the published unit price.

9. Catalog Code Cognizance Symbol

A two position code prefixed to National Stock Numbers to identify and designate the inventory control point, Office or agency which exercises supply management.

10. Item Name Self-explanatory.

11. Shelf Life Shelf Life

The shelf life span of material (in years) from the date of manufacture or previous inspection to the date of test for continued usefulness or disposition. Zero shelf life indicates that the item is non-deteriorative.

12. Unit of Issue Self-explanatory

Parameter Data

1. Procurement Order Cost

The amount of administrative costs associated with placing an order. The default value is \$650.00.

2. Shortage Cost

The cost associated with being in a back order position for a certain item. The default value is \$750.00.

3. Holding Cost Rate

The rate, when used with the item price, determines the costs associated with the cost of capital, obsolescence, and storage. The default value is 23 percent.

4. Minimum Acceptable Risk

The minimum allowed risk of being short in supply of an item. The default value is 10 percent.

5. Maximum Acceptable Risk

The maximum allowed risk of being short in supply of an item. The default value is 50 percent.

6. Optimal Lot Size Investment Rate

A constant used to factor in the anticipated opportunity cost (or cost avoidance) associated with the alternative quantity being evaluated. The default value is 10 percent.

7. Lead Time Demand Investment Rate

A constant used to factor in the anticipated opportunity cost (or cost avoidance) associated with the alternative lead time being evaluated. The default value is 10 percent.

8. Lower and Upper Bid Range Factor

The DOD specified minimum and maximum procurement quantity (in quarters). The default values are one and eight respectively.

Vendor Data

1. Vendor FSCM

The Federal Supply Code for Manufactures.

2. Vendor Set-up Cost

The one time cost to begin manufacturing.

3. First Article Cost

The cost associated with testing initial manufactured parts.

4. Prompt Payment Discount

A percent applied to the final buy quantity after the FCIM evaluation. The vendor specifies the rate and the period of time over which the discount may be taken by the Government.

5. Minimum Lot Size

The minimum quantity that can be bought at the quoted price.

6. Lead Time

The quoted lead time (in days). If phased deliveries apply, the quantity and lead time for each delivery is required. The quantities must add up to the MLS quantity.

APPENDIX B SAMPLE REPORTS

FLEXIBLE COMPUTER INTEGRATED MANUFACTURING
DECISION SUPPORT SYSTEM

DATE: 10/10/92
TIME: 21:07:55

ITEM / PARAMETER / BID RANGE DATA *****

SOLICITATION NO: 000187169

NSN: 000187169

BUYER: RCD

** ITEM DATA **

MAD:	4.6500	EOQ:	29
QTR'LY DMD:	5.4600	UNIT PRICE:	128.50
QTR'LY REQ:	5.4600	CATALOG CODE:	5R
PROD LT:	415.0000	ITEM NAME:	SHAFT SHOULDERED
PROC LT:	565.0000	SHELF LIFE:	0.00
REORDER POINT:	47		

** PARAMETER DATA **

PROCUREMENT ORDER COST:	650.00
SHORTAGE COST:	750.00
HOLDING COST RATE:	0.23
MINIMUM ACCEPTABLE RISK (RATE):	0.09
MAXIMUM ACCEPTABLE RISK (RATE):	0.10
OPTIMAL LOT SIZE INVESTMENT RATE:	0.10
LEADTIME DEMAND INVESTMENT RATE:	0.10
LOWER BID RANGE FACTOR:	1
UPPER BID RANGE FACTOR:	20

** BID RANGE DATA **

TOTAL PURCHASE REQUEST QUANTITY	0
CURRENT MATERIAL REQUIREMENT	0
LOWER BID RANGE LIMIT	6
UPPER BID RANGE LIMIT	110

FLEXIBLE COMPUTER INTEGRATED MANUFACTURING
DECISION SUPPORT SYSTEM

DATE: 10/10/92
TIME: 21:08:47

VENDOR DATA

SOLICITATION NO: 000187169

NSN: 000187169

BUYER: RCD

VENDOR NUMBER 3

		PRICE BREAKS		INCREMENTAL DELIVERIES			
MLS		PRICE	LT(DAYS)	QTY	LT	QTY	LT
1.	6	90.15	133	NONE			

 * FLEXIBLE COMPUTER INTEGRATED MANUFACTURING DATE: 10/10/92 *
 * DECISION SUPPORT SYSTEM TIME: 21:09:25 *
 *

** EVALUATION SUMMARY DATA REPORT **

 * SOLICITATION NO: 000187169 ITEM MANAGER: RCD *
 * NSN (FSCM-PN): 000187169 BUYER: PCD *
 * ITEM NAME: SHAFT SHOULDERED METHOD: OPTIMAL QUANTITY *
 *

* LOWER BID LIMIT: 6 UPPER BID LIMIT: 110 *
 * VENDORS RESPONDING (4): CPXXX NOSLX NACXX CNSYX *
 *

* VENDOR WITH LEAST TOTAL RELEVANT COST (TRC): NACXX *

	* SELECTED VENDOR *		* CURRENT LEVELS *	
* QUANTITY AND PRICE *	* QTY *	* PRICE *	* QTY *	* PRICE *
* BUY (ELS / TOTBUY) *	45	90.15	29	128.50
* OLS / EOQ *	45	90.15	29	128.50
* CURRENT MAT'L REQ'MT(CMR) *	0	90.15	0	128.50
* REORDER POINT *	31	N/A	47	N/A
* PRODUCTION LEADTIME *	133	N/A	415	N/A

	* SELECTED VENDOR *		* CURRENT LEVELS *	
* COSTS *	* TOTALS *	* SUB-TOTALS *	* TOTALS *	* SUB-TOTALS *
* ANNUAL TOTAL VARIABLE *	3041		4967	
* ANNUAL PURCHASE *		1969		2806
* ANNUAL ORDERING *		315		490
* ANNUAL HOLDING *		757		805
* ANNUAL SHORTAGE *		0		866
* CMR *	0		0	
* INVESTMENT OPPORTUNITY *	-9			
* ANNUAL TOTAL RELEVANT *	3032		4967	

* TOTAL ACQUISITION COSTS *	1056.75		3726.50	
* \$ VALUE BUY *		4056.75		3726.50
* \$ VALUE BUY DISCOUNT *		0.00		N/A
* ADDITIONAL \$ REQUIRED *	330.25			

ANALYSIS COMPUTER INTEGRATED MANUFACTURING
DECISION SUPPORT SYSTEM

DATE: 12/10/82
TIME: 01:11:57

***** DETAILED VENDOR EVALUATION REPORT *****

***** SOLICITATION NO: 000137102 *****

VENDOR: HADXX (3 OF 4)

***** ORDER COST: 0.00 FIRST ARTICLE COST: 0.00 PROMPT DISCOUNT RATE: 0.00 *****

***** INPUT DATA *****			
PB#	MLS	PRICE	LT
1	6	20.15	133

***** COMPUTED LEVELS DATA *****						
PB#	ELS	OLS	Q	RP	SL	EUS
1	45	45	45	21	14	0

***** PROCUREMENT DATA *****				
PB#	ELS	PROMPT PAYMENT	ADD'L \$	
PB#	\$ VALUE	DISCOUNT	ACQ'TION \$	ELS-TOTBUY
1	4056.75	0.00	4056.75	330.25

***** TRC SUMMARY DATA *****				
***** RELEVANT COSTS *****				
PB#	TOTAL	VARIABLE	INVESTMENT	CUR MAT'L
1	3032	3041	-9	0

***** TRC DETAILED DATA *****							
***** ANNUAL VARIABLE COSTS *****					***** INVESTMENT COSTS *****		***** CUR MAT'L *****
PB#	PURCHASE	ORDERING	HOLDING	SHORTAGE	OPT'ML LOT	LT DMD	\$ VALUE
1	1969	315	757	0	144	-153	0

APPENDIX C FCIM DSS FORMULAS

ANNUAL PURCHASE COST (APC) = ANNUAL DEMAND X PRICE

ANNUAL ORDER COST (AOC) = ((ORDER COST + SET UP COST +
1ST ARTICLE COST) X ANNUAL DEMAND) /
OPTIMAL LOT SIZE (OLS)

ANNUAL HOLDING COST (AHC) = HOLDING COST RATE X (OLS/2 +
SAFETY LEVEL) X PRICE

ANNUAL SHORTAGE COST (ASC) = SHORTAGE COST X EXPECTED
UNITS SHORT (EUS) X (ANNUAL DEMAND/
OLS)

CURRENT MATERIAL REQUIREMENT COST (CMRC)
= CMR QUANTITY X PRICE

OPTIMAL LOT SIZE OPPORTUNITY COST (OLSOPC)
= OLS INVESTMENT RATE X (OLS -
EOQ) X PRICE

LEAD TIME DEMAND OPPORTUNITY COST (LTDOPC)
= LTD INVESTMENT RATE X
(((ADMIN LT + (VENDOR LT/90) X QUARTERLY DEMAND) -
(QUARTERLY DEMAND X (PROCUREMENT LT/90)) X PRICE

ANNUAL TOTAL VARIABLE COST (ATVC) = APC + AOC + AHC + ASC

TOTAL RELEVANT COST (TRC) = ATVC + CMRC + OLSOPC + LTDOPC

LIST OF REFERENCES

1. Brauer, D. C., "Effect Of Lead Time And Service Level On Safety Stock for A Continuous Review Inventory System with Independent Demand", Production and Inventory Management, Second Quarter, 1985.
2. Bryant, B.B., "A Study of the Adequacy of the Navy Industrial Fund Accounting System for use with the RAMP SMP Facility", Masters Thesis, Naval Postgraduate School, June 1988.
3. Carr, L. P. and Ittner, C. D., "Measuring the Cost of Ownership", Draft Article submitted for publication, Not dated.
4. Fleet Material Support Office, "RAMP Decision Support System Documentation for Version 1.0", December 1991.
5. Gardner, T. A. Jr., "Cost Benefit Analysis of a Flexible Manufacturing System: The U.S. Navy's Rapid Acquisition of Manufactured Parts", Masters Thesis, Massachusetts Institute of Technology, May 1988.
6. Goodwin, T. D., "An Implementation Study of an Accounting System Design for the Naval Avionics Center", Masters Thesis, Naval Postgraduate School, June 1991.
7. Gupta, N. K., "Effect of Lead Time on Inventory- A Working Result", Journal of the Operational Research Society, Vol. 30, No. 5, 1979.
8. Jones, D. J., "JIT & The EOQ Model: Odd Couple No More!", Management Accounting, February 1991.
9. Magson, D. W., "Stock Control When the Lead Time Cannot be Considered Constant", Journal of the Operational Research Society, Vol. 30, No. 4, 1979.
10. Martin, M. P., "Performance Measurement in the RAMP SMP Facility", Masters Thesis, Naval Postgraduate School, June 1989.
11. Mayer, R. R., "Optimum Safety Stocks When Demands and Lead Times Vary", Journal of Purchasing and Materials Management, Spring 1984.

12. Meinich, M., "An Assessment of Relevant Costs in the Wilson EOQ Model", Masters Thesis, Naval Postgraduate School, December 1988.
13. Naval Supply Systems Command, "Rapid Acquisition of Manufactured Parts (RAMP) Strategic Implementation Plan", May 1989.
14. Nevison, C. and Burstein, M., "The Dynamic Lot-Size Model with Stochastic Lead Times", Management Science, Vol. 30, No. 1, January 1984.
15. OPNAV Instruction 4440.23, Procurement cycles and safety levels of supply for secondary items, February 1976.
16. U.S. Navy Ships Parts Control Center, "Project Q-Star, A Price, Quantity and Lead Time Bid Evaluation Procedure", 1985.
17. Weingart, Z., "Inventory Models for Slow Moving Items For The Israeli Navy", Masters Thesis, Naval Postgraduate School, March 1991.
18. Woolsey, G., "A Requiem for the EOQ: An Editorial", Production and Inventory Management Journal, Third Quarter, 1988.

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